

## PRESBYOPIC CONTACT LENS

This application is a continuation in part of application Ser. No. 078,462 filed Sept. 24, 1979, now abandoned.

This invention relates to an improvement in contact lens design and more specifically relates to contact lenses designed to correct presbyopia.

## BACKGROUND OF THE INVENTION

Contact lenses have been used for the correction of such disorders as myopia, hyperopia, aphakia, and astigmatism. Thus far, contact lenses have been less successful in the treatment of presbyopia, which is a defect of vision associated with advancing age characterized by loss of elasticity of the crystalline lens. The presbyopic patient lacks visual accommodation, i.e., the ability of an eye to adjust to see clearly objects that are close to or at intermediate distances from the eye without the aid of a suitable corrective lens. Presbyopia may begin to occur beginning at age forty.

The common correction for presbyopia is to use bifocal eyeglass lenses which have an upper portion ground for distance viewing, having, most commonly, a correction for myopia or hyperopia, and a lower portion with diopter add for near viewing. This solution is feasible in eyeglasses because the eyeball moves down as the patient looks down, and, therefore, the pupil of the eye moves relative to the lens.

The bifocal solution employed in eyeglasses has not lent itself readily to contact lenses. Contact lenses generally move with the eyeball and this permits contact lenses to be constructed of relatively small size with a diameter which may be slightly larger than the pupillary diameter of the eye or of a size which can extend beyond the cornea and into the scleral area. Bifocal contact lenses have been used which have a thick lower edge which is engaged by the lower eyelid when the patient looks down, causing the contact lens to slide upwards on the cornea relative to the pupil. Such lenses which move relative to the eye are hard to fit because the lens must be sized properly to be engaged by the lower lid. Moreover, the amount of movement of the lens must be accurately measured to determine the desired height of the bifocal segment.

When a patient has pronounced presbyopia, a bifocal lens, whether an eyeglass lens or a contact lens, may not provide a full range of good vision. In addition, if the lack of elasticity of the crystalline lens prevents significant accommodation, a corrective lens with two foci for close and distant viewing may be inadequate for intermediate viewing.

It has been found that contact lenses having spherical anterior surfaces and aspherical posterior surfaces may be advantageously used for the correction of presbyopia. U.S. Pat. No. 3,535,825 describes methods and apparatus for grinding and polishing aspheric contact lenses in the shape of conicoids of revolution. An aspheric posterior surface in the shape of an ellipsoid, a paraboloid, or a hyperboloid is lathe-cut into a contact lens blank by an appropriate cutting tool. The conicoid surface is thereafter polished to optical tolerance by a toroidal-shaped polishing tool, the polishing tool being disposed at an angle to the blank and rotated as the blank is oscillated and rotated thereagainst. Such a conicoid posterior surface, when used in conjunction with a generally spherical anterior surface, results in progres-

sively increasing diopter add away from the center of the lens. Despite the loss of focusing ability of the lens of the eye in presbyopic patients, the eye maintains the ability to focus through that part of the contact lens most appropriate for viewing an object at a particular distance, and thus a contact lens having varying diopter power will permit visual accommodation by a presbyopic patient.

An aspheric surface of a contact lens may be described in terms of its radii of curvature and its eccentricities. In a truly spherical surface, of course, all points thereon have the same radius of curvature and zero eccentricity. For an aspheric surface the term "radius of curvature" refers to the apparent radius of curvature along the meridian at a selected point on the surface. Apparent radii of curvature may be measured at any point on the surface of the lens by instruments such as a keratometer or preferably by a "Radiuscope", sold by American Optical Company.

Eccentricity is a measure of asphericity of a surface. In strict geometric terms, eccentricity is used to describe conic sections such as ellipses, parabolas, and hyperbolas and is the ratio of the distance from any point on the conic section to a focus and the corresponding directrix. A circle has an eccentricity of 0; an ellipse has an eccentricity of less than 1; a parabola has an eccentricity of 1; and a hyperbola has an eccentricity of greater than 1.

A conicoid of revolution is a conic section which has been rotated around its major axis. For a conicoid of revolution, at points away from the center it is possible to measure an apparent meridian radius of curvature and an apparent transmeridian radius of curvature and calculate the eccentricity therefrom, using the methods and apparatus described in U.S. Pat. No. 4,149,801. The eccentricity of the conicoid of revolution may be calculated from the formula:

$$\epsilon = \frac{\sqrt{1 - R_t/R_m}}{\sin \theta}$$

where:

$\epsilon$  is the eccentricity,

$R_m$  is the meridian radius,

$R_t$  is the trans-meridian radius; and

$\theta$  is the angular distance from the center of the center of the point at which the apparent radii are measured. (The angle  $\theta$  as used herein is actually the angle which the lens holder is displaced from horizontal for Radiuscopic examination according to the methods of U.S. Pat. No. 4,149,801. Technically, it is imprecise to describe an angle away from the center of a nonspherical surface, but the angle of the lens holder is a good approximation for surfaces having radii of curvatures of from about 6.5 to about 8.5).

While contact lenses have often been described in terms of conicoids of revolution, such shapes are idealized surfaces which may be only approximated in actual practice. Accordingly, the term radius of curvature as used herein will be used to describe the apparent meridian radius of curvature at any point, and eccentricity as used herein will refer to the apparent eccentricity at any point as calculated from the apparent meridian radius and from the apparent trans-meridian radius.

A presbyopic patient typically needs about 2.50 additional diopters for close reading than for normal distant viewing. For example, a nearsighted (myopic) person